THE EXPERIENCE OF MINDFULNESS FOR CHILDREN WITH AUTISM: AN EXAMINATION OF SELF-REPORT AND ELECTRODERMAL RESPONSE.

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A THESIS SUBMITTED TO

THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF MASTER OF ARTS

GRADUATE PROGRAM IN CLINICAL-DEVELOPMENTAL PSYCHOLOGY

YORK UNIVERSITY TORONTO, ONTARIO

AUGUST, 2018

Abstract

Little is known about how children with autism respond to mindfulness activities within cognitive behavioural therapy (CBT). As many children with autism also struggle to report their emotional experience, this study explored how enjoyment ratings of therapeutic activities within a CBT intervention were associated with physiological arousal, and whether patterns of arousal differed for mindful as compared to computer activities. Data was collected during a 10-week CBT-based emotion regulation intervention for children with autism (N = 35). Multilevel growth modeling revealed that greater mindfulness enjoyment was predicted by higher autism symptoms, greater child motivation to participate in therapy and greater child worry dysregulation. Greater computer enjoyment was predicted by greater child motivation to participate in therapy. Lower mindfulness arousal was predicted by higher child-reported ability to cope with worry. Findings lay groundwork towards a psychological profile of school-age children with autism who may derive particular enjoyment from mindfulness activities.

Acknowledgements

I would like to sincerely thank my supervisor, Dr. Jonathan Weiss, for the encouragement, insight and support that made this project possible. I would also like to thank the members of my thesis committee, Dr. Christine Till, Dr. Jennine Rawana and Dr. Joseph Baker, for their incredibly thoughtful feedback. Thank you to Flora Roudbarani and Julia Martini for invaluable help with time-tracking, Chris Rowley for flawless Ledalab/Matlab coding and Dr. Rob Cribbie and Dr. Dave Flora for expert statistical consulting. A very special thank you to the wonderful children, families and therapists who participated in the study.

This research was conducted with support from a Joseph Armand Bombardier Canada Graduate Scholarship-Master's from the Social Sciences and Humanities Research Council, an Autism Scholars Award from the Council of Ontario Universities, and a York University Sammy Graduate Scholarship in Autism Research.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

The experience of mindfulness for children with autism:
An examination of self-report and electrodermal response.

Over the last 20 years, cognitive behavioural intervention (CBT) has been explored as a non-pharmacological means to address a wide range of emotional and behavioural difficulties experienced by children with autism (Ho, Stephenson, & Carter, 2015). Although CBT programs vary in their approach and target focus, overall, the intent is to provide children with increased understanding about the internalizing and externalizing symptoms they experience, as well as techniques to reduce distress (Ho et al., 2015). Many of these programs incorporate strategies designed to help children learn to focus attention on their breathing (described as "calming" and "relaxing"); this type of practice of sustained attention and awareness is central to mindfulness practice (Kabat-Zinn, 2003), although not defined as such in these contexts. Based on Eastern meditation techniques, mindfulness-based therapy (MBT) is intended to increase an individual's awareness in the moment (e.g. of themselves, others and the world around them), as well as their ability to approach experiences with focus and acceptance (Kabat-Zinn, 2003).

Emerging evidence indicates that MBT may be a helpful method to reduce distress for children with autism (Cachia, Anderson, & Moore, 2016). In a therapeutic context for children, mindfulness skills are taught by scaffolding awareness of sensations in the body, and practicing techniques such as noticing, describing and acceptance (Thomson, Burnham Riosa, & Weiss, 2015). Given that children with autism experience high rates of alexithymia (difficulties understanding how internal sensations map onto one's emotions; Milosavljevic et al., 2015), with more than 40% of such children diagnosed with at least one co-morbid anxiety disorder (van

Steensel, Bögels, & Perrin, 2011), as well as ADHD, depression and conduct problems (Jang et al., 2013; Kim, Szatmari, Bryson, Streiner, & Wilson, 2000; Simonoff et al., 2008; Totsika, Hastings, Emerson, Lancaster, & Berridge, 2011), MBT provides the promise of a particularly useful skillset. As reported by parents, MBT interventions have been associated with improvements in anxiety and thought problems (as assessed by the CBCL) for school-age children with autism (Hwang, Kearney, Klieve, Lang, & Roberts, 2015), attention and hyperactivity for pre-school age children with autism and mild to moderate intellectual disabilities (Neece, 2014), improvements in aggression, well-being and social responsiveness for teens with autism (de Bruin, Blom, Smit, van Steensel, & Bögels, 2015; Singh et al., 2014; Singh, Lancioni, Manikam, et al., 2011a; 2011b), and in quality of life and self-control for teens with internalizing and externalizing disorders and autism (Bögels, Hoogstad, van Dun, de Schutter, & Restifo, 2008).

However, little is known about MBT from the child's perspective. Participation is time-intensive, requires commitment to regular practice, and suggests a certain openness to accept abstract concepts; a structure which may not suit all children on the spectrum. Further, the majority of MBT research in the field of autism has focused on parent-mediated designs: Skills are either taught only to parents (intended to change both parental and child behaviour), or to parents and children concurrently (Hwang et al., 2015).

Child-Report in Mindfulness-based Therapy

Youth with Autism. To date, only three studies of MBT have included self-report measures for youth with autism. In the first study, Bogels et al. (2008) found moderate to large improvements in mindful awareness, personal goals, externalizing symptoms and attention problems reported by 14 adolescents with externalizing problems (two of whom had autism). The group did not report change in overall quality of life, and the study only documented the effects of participating in the intervention, not adolescents' experience of engaging in mindfulness practice. In the second study, 23 adolescents with autism reported significant improvements in quality of life – as well as reductions in rumination – but no change in mindful awareness, worrying, or core autism symptoms (De Bruin et al. 2015). Adolescents also provided a mindfulness "usefulness" rating (*1 – not useful to me; 2 – somewhat useful to me; 3 – very useful to me*) via a post-intervention evaluation questionnaire; overall, adolescents reported their experience as "somewhat" to "very useful" (de Bruin et al., 2015). Most recently, Ridderinkhof, Bruin, Blom, & Bögels (2017) documented the effects of participation following a 9-week group MBT program delivered to groups of children and adolescents, as well as their parents. All participants answered a brief, open-ended post-test questionnaire, asking what they had learned, if they had experienced any changes, and if they would like to share any opinions about the program. Children under the age of 12 (n = 8) also completed self-reports about stress, sleep patterns and emotional well-being; adolescents (n = 19) completed the latter three, as well as questionnaires on internalizing and externalizing symptoms, rumination and mindful awareness. Youth and parent qualitative findings were grouped with anecdotal examples under three primary themes (*mindfulness skills, improved well-being, little to no change*) with a range of sub themes (e.g. applying meditation; coping with difficult experiences), without specification of whether data reported was attributed to youth, parents, or both. Youth reported significantly decreased rumination at post-test, with a number of improvements at 2-month (i.e. externalizing symptoms, attention problems, and stress, with further reductions in rumination), and 1-year follow-up (i.e. increased emotional well-being, with attention problem reductions maintained). No improvement in mindful awareness was reported at any timepoint. Given that parents reported significant improvement in their own emotional-behavioral functioning, stress, and reactivity following participation in the program, the decreased stress within the home environment may also explain the later improvement in youth well-being and reductions in clinical symptoms. Additionally, 50% of youth reported engaging in an additional form of psychotherapy during the trial (Ridderinkhof et al., 2017).

Youth without Autism. In the non-autism MBT literature, for children and teens with and without clinical issues, mixed results have also been found. For example, no child-reported improvement was noted for mood or depressive symptoms after primary school children (without clinically-significant symptoms at baseline) received either 8 weeks of MBT or emotion awareness education. However, teacher-reports indicated significantly reduced internalizing and externalizing symptoms and increased mindfulness in the MBT condition (Crescentini, Capurso, Furlan, & Fabbro, 2016). In another school-based study of MBT, adolescents reported no improvement at post-test or 3-month follow-up for any outcome variables including anxiety, depression, or well-being (Johnson, Burke, Brinkman, & Wade, 2016). In this case, part of the sample had reported clinically significant symptoms at baseline (depression: 21.6%, anxiety: 22.2%). In contrast, group MBT administered in a specialized school for chronically ill children (Ages = 8 – 18 years; M = 13) was related to significant improvements in child-reported anxiety symptoms at post-test (Lagor, Williams, Lerner, & McClure, 2013), and a 10-week MBT program for incarcerated youth was related to significant improvements in self-regulation, although no change in mindfulness, impulsivity or perceived stress was noted (Barnert, Himelstein, Herbert, Garcia-Romeu, & Chamberlain, 2014). Findings from these last two studies suggest that children and adolescents may be more attuned to positive changes following MBT when their baseline level of distress is severe; likewise, non-clinical symptom change may be too subtle for children to assess.

Physiological Response

The use of objective measurement during mindfulness activities may help to expand our understanding of children's experience. For example, evidence indicates that while some children with autism may struggle to report the extent of their emotional experience (expressing only a restricted range of affect), their physiological responses do show variability (Ben Shalom et al., 2006). Electrodermal activity (EDA), also known as skin conductance, is a non-invasive measurement of electrical potential on the skin, activated by an increase in perspiration during psychological arousal (Boucsein et al., 2012). As sudomotor innervation (leading to perspiration) occurs in the sympathetic nervous system, EDA is often used as a representation of emotional reactivity. Measurement may reflect either an overall, baseline skin conductance level (SCL or "tonic"), reactivity to a discrete stimulus occurring within a specified window immediately following the presentation (SCR, skin conductance or "phasic" response), or a combination of both (Boucsein et al., 2012). Studies of EDA in children with autism without intellectual disability have primarily focused on measures of SCRs, although the findings are mixed. O'Haire, McKenzie, Beck, & Slaughter (2015) found that school-age children with autism displayed greater changes in SCR relative to non-affected peers when exposed to both toy and activity conditions in a continuous setting; some studies demonstrate a relationship between elevated SCRs and social stimuli (Joseph, Ehrman, McNally, & Keehn, 2008; Kylliäinen & Hietanen, 2006), one found no difference in SCRs for youth with autism and non-affected peers viewing non-social, emotionally evocative stimuli (Ben Shalom et al., 2006), another noted differing response patterns, but non-significant group differences in a study of an anxiety-provoking task in children with autism and non-affected peers (Kushki et al., 2013), and young toddlers with autism have been shown to exhibit the same SCRs as controls without autism during presentation of non-social, loud auditory stimuli (McCormick et al., 2014).

There is also an emerging trend to examine emotional reactivity via SCL within a continuous, naturalistic context. Prince et al. (2017) examined changes from baseline SCL following toddlers' participation in a semi-structured assessment with interactive and passive activities, finding greater changes in SCL for the autism group compared to controls across all activities (i.e., suggesting a comparatively heightened state of emotional arousal). Similarly, O'Haire et al. (2015) found that a guinea pig condition (intended to test the soothing effect of a companion animal) resulted in significantly lowered SCL and SCRs for children with autism, while increasing SCL for children without autism, indicating that even a quasi-therapeutic condition can differentially influence skin conductance in this population. Currently, only one study has used EDA to examine treatment response for MBT: Lush et al. (2009) found significant reductions in SCL at post-test for 24 adults who participated in an 8-week mindfulness-based stress reduction program. To date, no studies have explored if mindfulness training can similarly reduce SCL or SCRs in children with autism.

Child-Level Characteristics

Demographic/clinical. There is also a lack of information about whether specific child characteristics differentially affect children's ability to benefit from MBT. Some evidence suggests that demographic and clinical characteristics such as younger age, higher IQ, higher language ability, greater adaptive skills, and lower social anxiety symptoms, are all associated with improved treatment outcomes in psychotherapy for youth with autism (Ben-Itzchak, Watson, & Zachor, 2014; Magiati, Moss, Charman, & Howlin, 2011; Pellecchia et al., 2016). However, in another study, no association was found between baseline autism symptom severity and cognitive changes for 6- to 8-year olds, following one year of school-based behavioural intervention (Pellechia et al., 2016).

Motivation and Worry. Emerging evidence in the literature for youth without autism indicates that children's motivation to participate in an intervention may be a key determinant for therapeutic success, including in MBT: Interventions targeting treatment readiness and motivation for adolescents with substance abuse difficulties resulted in improved post-intervention gains (Becan et al. 2015). Similarly, for children with ADHD, poorer task-persistence has been associated with reduced motivation (Dekkers et al., 2017), and for adults participating in an MBT intervention for headache pain, higher pre-treatment motivation was associated with greater improvement in pain interference at post-test (Day, Halpin, & Thorn, 2016). In targeting major depression and suicidal ideation for adults, attrition was significantly associated with being younger, showing higher cognitive reactivity (i.e. less ability to regulate emotions following a stressful mood induction), and reporting higher levels of worry (measured as ruminative thoughts) than for those who completed treatment (Crane & Williams, 2010).

Maladaptive expression of worry symptoms has also been linked to reduced emotion awareness in studies of young children without autism (Zeman, Cassano, Suveg, & Shipman, 2010; Zeman, Shipman, & Penza-Clyve, 2001). Zeman et al. (2010) found that boys' inhibition of worry expression was associated with higher parental ratings of dysregulated emotional expression, and boys' self-reported worry dysregulation was strongly associated with poor emotional awareness.

Practice Over Time. Finally, a meta-analysis of 8-week MBT for major depression in adults indicates evidence that mindfulness practice improves over time (Lenz, Hall, & Bailey Smith, 2016). Post-intervention results showed a significant treatment effect for MBT as compared to either no treatment or alternative treatment conditions; at follow-up, analyses showed an even larger treatment effect for MBT as compared to post-intervention effect sizes, suggesting a delayed improvement in mindfulness skills may have taken place. That said, these last results were only calculated from four studies examining change over time, and should be interpreted with caution. When comparing MBT to alternative treatment conditions at post-intervention (seven studies), the mean effect size was smaller; the authors posit this finding indicates that differences in outcome change across active treatment conditions could be expected to even out over time (Lenz et al., 2016).

In sum, despite increasing interest in MBT as a means to improve the emotional well-being of children with autism, there is wide variability in findings, as well as a lack of studies that incorporate child-focused measures and control groups. Further, to date, no research has examined whether individual child characteristics contribute to treatment response in MBT. There is a critical need to understand *how* children with autism experience MBT, and importantly, to clarify whether the experience differs significantly from other, less abstract therapeutic activities which may require less buy-in from the child at the beginning of treatment. The current study addressed these gaps by examining the following exploratory research questions:

1. How are children's enjoyment ratings of mindfulness activities related to their physiological (emotional) response during practice? Does this relationship differ for a computer-based therapeutic activity?
    a. Hypothesis: Children's self-report ratings of mindfulness activities would be negatively correlated with SCL. That is, on average, the more positively a child rated their mindfulness experience, the lower their mindfulness SCL.
    b. Hypothesis: Given that computer-based therapeutic activities were intended to elicit moderately active participation and problem-solving (see Table 1), higher enjoyment ratings would be positively correlated with SCL.
2. Do specific baseline demographic, clinical and motivational factors predict change in children's enjoyment of MBT, and SCL during practice? Does the same pattern hold for computer-based activities?
    a. Hypothesis: Child mindfulness enjoyment will increase over time as a function of less core autistic symptoms, greater adaptive skills and more ability to cope at the outset (suggesting greater ability to understand abstract concepts), as well as greater psychopathology severity, greater worry, less ability to regulate emotions, and greater motivation (higher clinical difficulties and greater need for change may be related to greater treatment enjoyment).

b. Hypothesis: Child SCL during in-session MBT practice will decrease over time as a function of less core autistic symptoms, greater adaptive skills, more ability to cope and greater psychopathology severity, greater worry, less ability to regulate emotions, and greater motivation to participate in the overall intervention.

c. No a-priori hypothesis for computer-based activities

Method

This study examined data collected during treatment sessions of the *Secret Agent Society: Operation Regulation (SAS:OR)*, a 10-week manualized, randomized controlled cognitive behavioural intervention administered at York University from 2013 - 2017 (for a detailed description of the larger study, see [Weiss et al., 2018]). Children with autism each received ten, 60-minute, individual therapy sessions from a graduate-level therapist. The child's primary caregiver attended all sessions and was actively encouraged to provide support for their child (i.e. home practice of new skills and positive reinforcement). Each session incorporated a review of homework practice and skills learned the previous week, teaching and practice of new concepts through a spy-themed workbook, role-play and computer-based activities, as well as positive reinforcement with points exchanged for a reward at the end of the session. In six of the ten sessions (1-3 and 5–7), children engaged in a psychoeducational computer activity teaching skills related to emotion awareness and regulation**,** followed by a brief mindfulness activity, which the therapist read from a standardized script (Table 1).

Table 1. *Descriptions of mindfulness and computer activities by session.*

Session	Mindfulness Activities	Computer Activities
1.	Breath Analyzer - *practice mindful breathing (begin to focus on the breath)*	Spot the Suspect/The Line Up – *recognize emotions using facial cues, posture & context*
2.	Body Scan – *practice awareness of physiological body sensations*	Voice Verification - *practice decoding emotions using tone of voice*
3.	Body Scan – *repeat practice*	Detective Laboratory/Degrees of Delight & Distress – *link physiological arousal with emotions*
5.	O2 Regulator – *learn & practice slow, mindful breathing (shifting attention from upsetting emotions)*	Crime at the Cathedral – *learn how thoughts affect emotions which affect behavior*
6.	Enviro-Body Scan – *practice awareness of body sensations and environmental cues*	Detective Flight Challenge – *explore different outcomes of high arousal*
7.	Enviro-body scan – *repeat practice*	Enemy Thought Destruction – *identify unhelpful thoughts and helpful alternatives*

Note: As no mindfulness activities were administered in Sessions 4, 8, 9 and 10, these sessions have been omitted.

Participants

In total, 69 children with autism (ages 8 – 12) and their primary caregivers participated in the intervention. Children included in the larger intervention study demonstrated IQ scores in the average range (>79) via the Matrix Reasoning and Vocabulary subtests of the *Wechsler Abbreviated Scale of Intelligence, 2nd Edition* (*WASI-II; Wechsler, 2011)* and autism symptomatology above a cut-off of 12 on the *Social Communication Questionnaire* (*SCQ*; Rutter, Bailey, & Ames, 2003; Schanding, Nowell, & Goin-Kochel, 2012). Parents provided copies of the child's original diagnostic report, or if not available, the *Autism Diagnostic Observation Schedule, 2nd Edition* (ADOS-2; Lord et al., 2012) was administered by a graduate researcher to confirm a diagnosis of autism.

For this study, due to large amounts of missing or corrupted EDA and video data, participants were included if a) both skin conductance data and video files were available, b) data were available for at least two sessions out of the six, and c) if only two sessions were available, each of those sessions fell in two of three different combined time-points (Timepoint 1 (T1): Session 1/Session 2; Timepoint 2 (T2): Session 3/Session 5; Timepoint 3(T3): Session 6/Session 7). The final sample included 35 children (f = 1; Age: *M* = 9.8 years, *SD* = 1.3; IQ: *M* = 104.2, *SD* = 11.8; SCQ: *M* = 21.8, *SD* = 4.4). Parents reported that 44.1% of participants took one or more daily psychotropic medication during the intervention (including antipsychotics, stimulants and antidepressants); as some research suggests that stimulant use may increase SCL in hyporeactive boys with ADHD (Conzelmann et al., 2014), Wilcoxon Signed Rank tests were used to confirm that there were no differences between children who took medication as compared to those who did not for all outcome variables. Additional demographic information is outlined in Table 2.

Table 2. *Participant demographic characteristics (N = 35)*

	n	(%)
Child Ethnicity[a]		
White/Caucasian	24	(80)
Other	6	(20)
Psychotropic Medication[b]		
Antipsychotic/Stimulant[c]	7	(20.6)
Mood-Related/Other[d]	8	(23.5)
None	19	(55.88)
Parent's Highest Level of Education[e]		
High school/some college	3	(9.7)
Bachelor or Associate's degree	20	(64.5)
Master's degree or above	8	(25.8)
Family Income[e]		
< $49,999	1	(3.2)

$50,000 - $99,999	4	(12.9)
$100,000 - $200,000	15	(48.4)
> $200,000	6	(19.4)
Prefer not to disclose	5	(16.1)

[a] 5 items missing; [b] 1 item missing; [c] taking one or more antipsychotic or stimulant; [d] taking one or more mood stabilizer, SSRI, SNRI or NDRI; [e] 4 items missing

Measures

Activity Enjoyment (*Self-Report – Mindfulness/Computer*). At the end of each session, children were asked to complete a brief evaluation of how much they liked participating in mindfulness and computer-based activities, by providing a numerical rating chosen from a 5-point Likert scale with numbers and corresponding emotional faces faces (*1 – sad face to 5 – happy face*). Forms were completed while the therapist left the room, then placed in a sealed envelope for confidential collection by a research assistant. As shown in Table 3, ratings within each combined timepoint (i.e. Session 1 and Session 2) were averaged for each participant. Higher scores represented more enjoyment. Enjoyment descriptives for all six sessions are outlined in Appendix B.

Table 3. *Descriptives for enjoyment by activity and combined timepoint*.

	Mindfulness T1 (n = 34) / T2 (n = 35) / T3 (n = 35)			Computer T1 (n = 35) / T2 (n = 35) / T3 (n = 35)		
	M (SD)	*Md*	Range	*M (SD)*	*Md*	Range
T1	3.94 (.83)	4.0	2.5 – 5.0	4.33 (.71)	4.5	2.5 – 5.0
T2	3.83 (1.13)	4.0	1.0 – 5.0	4.66 (.51)	5	3.0 – 5.0
T3	4.04 (1.02)	4.0	1.5 – 5.0	4.43 (.72)	4.5	3.0 – 5.0

T1 = Timepoint 1 (Session 1 & Session 2); T2 = Timepoint 2 (Session 3 & Session 5); T3 = Timepoint 3 (Session 6 & Session 7)

Activity Skin Conductance Level (*SCL – Mindfulness / Computer*). Participants' physiological response during participation in session-based mindfulness and computer activities was assessed via measurement of continuous skin conductance level (SCL). SCL data were collected from all participants using a wireless, wristband sensor (Q-Sensor, Affectiva Inc., Waltham, MA), which was placed on the inner side of the child's non-dominant wrist by the therapist at the beginning of each session. All sessions were video-recorded, unless the child expressed severe discomfort with the camera. Session videos were viewed, then timed to match a standardized list of prompts indicating the start and finish of each activity (e.g. *Therapist reads the line "now open your eyes…"*); video timing was then matched to the corresponding SCL export time in Excel, and segments were trimmed to activity length. Video time tracking was completed with the assistance of two undergraduate research assistants. Following training, each research assistant demonstrated strong reliability by providing activity timing for five complete sessions, previously timed by the author; all start and end times tracked matched the author's timing within one second or less. For segment trimming, as the duration of mindfulness activities varied slightly across participants within each session (due to accommodation of individual child needs), the total duration of each child's mindfulness activity was calculated first, then the computer activity duration for that session was tailored to match. Additionally, in Session 7, 57% of participant computer activities (n = 12) lasted for less time than their respective mindfulness activities and in such cases, the full duration of each computer activity was retained. Since activity duration significantly differed between mindfulness and computer activities at T3 ($Z = -2.98$, $p < .01$, $r = -.62$), and near significant correlations were found between activity duration and SCL for both activities (see Table 9), duration was controlled for in the SCL growth curve analyses. There were no other differences between activity durations (all p < .05), as shown in Table 4.

SCL descriptives for all six sessions are outlined in Appendix B.

Table 4. *Descriptives for SCL and duration by activity and combined timepoint*.

	Mindfulness T1 (n = 32) / T2 (n = 26) / T3 (n = 27)						Computer T1 (n = 31) / T2 (n = 22) / T3 (n = 26)					
	SCL			Duration (s)			SCL			Duration (s)		
	M [a] *(SD)*	*Md* [b]	Range	*M (SD)*	*Md*	Range	*M* [a] *(SD)*	*Md* [b]	Range	*M (SD)*	*Md*	Range
T1	.66 (.44)	.50	.22-1.8	135 (41)	120.5	85-242	.77(.54)	.56	.19-2.0	135(41)	120.5	85-242
T2	.78 (.54)	.62	.18-2.0	162 (58)	151.3	72-281	.55(.28)	.56	.22-1.1	162(58)	151.3	72-281
T3	.67 (.37)	.65	.24-1.5	180 (39)	182.8	105-276	.55(.33)	.46	.21-1.6	143(46)	152.0	62-218

[a] *Represents square-root transformed mean, in µS*
[b] *Represents square-root transformed median, in µS*

SCL = skin conductance level; T1 = Timepoint 1 (Session 1 & Session 2); T2 = Timepoint 2 (Session 3 & Session 5); T3 = Timepoint 3 (Session 6 & Session 7); Duration = Activity duration in seconds

Data were down-sampled to 4Hz[1] using Ledalab Version 3.4.9 (www.ledalab.de) in MATLAB Version 9.1.0 (MathWorks, Natick, MA). Additionally, following procedure outlined by O'Haire et al. (2015), data were smoothed with a 5-sample Hanning window to reduce noise, filtered using a first order, low-pass Butterworth filter (cut-off = .05 Hz), then square-root transformed and averaged. Therefore, each final SCL segment was defined as the square-root transformed mean of the tonic skin conductance data (i.e. representing the mean level of a participant's emotional response during the activity). Higher means reflected higher levels of arousal. In the case of segments with extremely low means, rather than assuming participants were low-responders when loose or slight misplacement of the sensors might also explain low data output, processed SCL segments with pre-transformation mean values below a minimum cut-off of .05 microSiemens (μS) were discarded (Benedek & Kaernbach, 2010).

Demographic predictors. Two demographic variables were examined: IQ and child age (see Table 5 for descriptives). Gender was not included as a variable due to the small number of females in the sample (n = 1). All demographic information was collected from a standard demographics form completed by parents at baseline, with the exception of IQ, as outlined above.

Clinical predictors. Seven clinical predictor variables were examined for each participant: Child-reported worry symptoms via three subscales, parent-reported autism symptomatology, emotion regulation and adaptive skills, and clinician-rated psychopathology severity. Autism symptomatology was measured via the SCQ, as outlined above. All clinical

[1] Data were collected with four spywatch devices; all were set at different sampling rates (4 Hz, 8 Hz, 16 Hz, 32 Hz). Following consultation with Dr. Matthew Goodwin (Goodwin, 2016), it was recommended to downsample all data to the lowest level (4Hz).

measures were completed once, at baseline.

Child-reported worry was measured via the *Children's Worry Management Scale* (CWMS; Zeman, Cassano, Suveg, & Shipman, 2010). The 10-item scale was developed to encompass internalized and externalized worry expression via three subscales: Inhibition (suppression of worry), Dysregulation (over-expression of worry) and Coping (adaptive strategies for addressing worry). Items are rated on a 3-point scale (*1 - hardly ever to 3 - often*), and were completed by children with the assistance of a research assistant. In this sample, internal consistency for children's ratings ranged from strong (Inhibition: $\alpha = .85$) to acceptable (Dysregulation: $\alpha = .59$; Coping: $\alpha = .51$).

Emotion regulation was measured with the *Emotion Regulation and Social Skills Questionnaire* (ERSSQ-P; Beaumont & Sofronoff, 2008), a 27-item caregiver report developed specifically for use with children with autism. Items are rated on a 5-point scale (*0 – never to 4 – always*), with higher scores indicating a child's greater ability to regulate emotions and adaptively navigate social situations. The measure has shown strong consistency ($\alpha = 0.90$) and validity ($r = 0.86$) for use with parents of children with autism (Butterworth et al., 2014).

Children's adaptive skills were measured via the Adaptive Skills composite of the *Behavioral Assessment Scale for Children*, 2nd Edition (BASC-2; Reynolds & Kamphaus, 2004). The composite reflects caregiver ratings for a child's ability to engage in day-to-day, pro-social, leadership and study skills, and comfort with functional use of communication. In the current sample, the composite demonstrated good internal consistency ($\alpha = .75$), falling in line with previous findings of good to strong consistency ($\alpha = .73$ to $.87$) and high test-retest reliability ($\alpha = .90$) in a sample of children with autism six – 11 years of age (Lopata et al., 2013). Higher scores represent greater skill ability.

Overall severity of psychopathology was measured via the *Clinical Global Impression – Severity* scale (CGI-S; Guy, 1976). Evaluations were completed by a psychologist who reviewed each child's complete baseline score summaries from the BASC-2, and Anxiety Disorders Interview Schedule for DSM-IV: Parent Version (ADIS; Silverman & Albano, 1996), before assigning an overall rating of psychopathology severity on a 7-point scale (*0 – no illness to 6 – serious illness*). The CGI-S is frequently used to provide an overall assessment of symptom severity in evaluations of cognitive behavioural therapy for children and adolescents with autism (Ehrenreich-May et al., 2014; Sung et al., 2011; Wood et al., 2009).

Motivational predictor. At baseline, children answered three questions assessing their motivation to participate in the intervention as a whole (*"Show me how much you want to participate"; "Show me how much you want to change"; "Show me how hard you're willing to work"*). These three items were then averaged to create a Motivation scale, similar to the Motivation for Youth Treatment Scale (Breda & Riemer, 2012). Items were rated on a 9-point scale (*0 – not at all to 8 – very much*), with higher ratings representing higher motivation. The composite showed good internal consistency within the sample ($\alpha = .72$).

Analysis

Statistical processing and analyses were completed with IBM SPSS Version 24.0 (data cleaning and correlations) and R Studio Version 1.0.136 (packages lme4 v1.1-15; MASS v7.3-47, Matrix v1.2-12; multilevel v2.6; psych v.1.7.3.21). Data points were considered outliers and removed if three standard deviations or more from the mean, and if removal improved the distribution via visual inspection of boxplots (Osborne & Overbay, 2004). Data from the six sessions were combined into three timepoints (T1, T2, T3); if a participant had both items within the timepoint (e.g., Session 1 and Session 2), the mean was taken; if only one item was available, that item was retained. Statistical replacement was not conducted for missing items in order to preserve the individual variability in the sample.

To examine associations between children's enjoyment during mindfulness activities (mindfulness enjoyment) and SCL during mindfulness practice (mindfulness SCL), bivariate Spearman's correlations were calculated for all dependent variables across the three combined timepoints. A second set of pairwise correlations were then run to explore the pattern of these relationships for computer-based activities (computer enjoyment/computer SCL). Associations within and between timepoints for enjoyment and SCL were also examined for consistency. Given the small sample size, correlations were examined both for statistical significance and effect size; predictor variables that were correlated with outcome variables (with p-values $\leq .10$; Schumm, Pratt, Hartenstein, Jenkins, & Johnson, 2013) were retained for subsequent growth modeling. Wilcoxon Signed Rank tests were also calculated to determine whether enjoyment and SCL outcomes significantly differed by activity (mindfulness/computer), at each timepoint.

Next, a series of mixed effect regression growth models was used to examine each outcome variable (i.e. mindfulness enjoyment, computer enjoyment, mindfulness SCL, computer SCL) with respect to a) change over time and b) change over time as a function of significantly associated baseline characteristics (Bliese, 2016; Jain et al., 2007; O'Haire et al., 2015; Shek & Ma, 2011). Notation used to model these relationships is detailed in Appendix A. Repeated measurements for enjoyment, SCL, activity duration and Time (coded as T1 = 0, T2 = 1, T3 = 2) were nested within each child (Level 1), and baseline characteristics, including autism symptom severity, motivation, worry coping, worry dysregulation and adaptive skills, were entered as fixed effects (Level 2). Predictor variables were grand-mean centered to assist with ease of interpretation. Variables with non-significant contributions of $\beta \leq .01$ were excluded from final models, in order to preserve degrees of freedom (Bliese, 2016).

Results

Descriptive statistics for baseline child characteristics are summarized in Table 5, below.

Table 5. *Descriptives for demographic, clinical and motivational predictors.*

	Mean	*(SD)*	*Md*	Range
Demographic				
Age	9.77	1.33	10	8 - 12
IQ	104.18	11.81	103	80 - 132
Clinical				
CGI-S	4.06	1.65	4.5	0 - 6
SCQ	21.77	4.43	22	13 - 30
ERSSQ	49.82	10.59	50.5	27 - 69
BASC - Adaptive Skills	36.94	7.34	34	26 - 52
CWMS - Inhibition	7.30	2.59	7	4 - 12
CWMS - Dysregulation	5.06	1.69	5	3 - 9
CWMS - Coping	6.38	1.76	7	3 - 9
Motivation	4.93	2.24	5.33	0 - 8

IQ = Wechsler Abbreviated Scale of Intelligence – 2 subscales; *CGI-S = Clinical Global Impression – Severity scale; SCQ* = Social Communication Questionnaire-Lifetime Version*; ERSSQ = Emotion Regulation in Social Situations Questionnaire; BASC= Behavior Assessment System for Children, 2nd Edition; CWMS = Children's Worry Management Scale*

Research Question 1

Associations between enjoyment and SCL. As shown in Table 6 (mindfulness activities; *Hypothesis 1a*) and Table 7 (computer activities; *Hypothesis 1b*), Spearman's correlations revealed that enjoyment ratings and SCL were not significantly associated at any of the three timepoints, for either activity. Enjoyment at T1 was strongly correlated with ratings at T2 for both activities (mindfulness: $r_s = .60$, $p < .001$; computer: $r_s = .56$, $p < .001$). Additionally, moderate to strong associations were noted for mindfulness enjoyment between T1-T3 ($r_s = .43$, $p = .01$) and T2-T3 ($r_s = .65$, $p < .001$); this pattern differed for enjoyment ratings of computer activities, which were not significantly correlated between sessions.

SCL during mindfulness activities (Table 6) showed moderate correlations among T1 and T2 ($r_s = .40$, $p = .05$), T1 and T3 ($r_s = .47$, $p = .02$), and T2-T3 ($r_s = .51$, $p = .02$). No significant or trend-level associations were noted in SCL during computer activities.

Table 6. *Spearman's correlations for mindfulness activities: Child enjoyment and SCL by timepoint.*

Mindfulness Variables	1	2	3	4	5	6
1. Enjoyment T1	-					
2. Enjoyment T2	.60***	-				
3. Enjoyment T3	.43**	.65***	-			
4. SCL T1	.05	.14	.24	-		
5. SCL T2	.12	-.04	-.09	.40*	-	
6. SCL T3	.06	<.01	.04	.47*	.51*	-

*p <.05; **p <.01, ***p < .001

Table 7. *Spearman's correlations for computer activities: Child enjoyment and SCL by timepoint.*

Computer Variables	1	2	3	4	5	6
1. Enjoyment T1	-					
2. Enjoyment T2	.56***	-				
3. Enjoyment T3	-.03	.14	-			
4. SCL T1	-.03	-.21	-.17	-		
5. SCL T2	-.13	-.09	.06	.28	-	
6. SCL T3	.05	-.26	-.09	.26	.23	-

***p < .001

Research Question 2

Differences between mindfulness and computer activities. Wilcoxon Signed Rank t-tests revealed significantly higher median enjoyment ratings for computer activities at each timepoint (T1: Z = -2.55, p = .01, r = -.44; T2: Z = -3.99, p <.001, r = -.67; T3: Z = -2.06, p = .04, r = -.35). For SCL, no significant differences between activities were observed at T1 or T3. At T2, however, median SCL during mindfulness activities was higher than for computer activities (Z = -2.73, p = .01, r = -.61).

Preliminary associations: Enjoyment, SCL and baseline characteristics. As shown in Table 8 (*Hypothesis 2a: Part 1*), greater mindfulness enjoyment at T1 and T3 was associated with lower IQ (T1 (trend-level): r_s = -.33, p = .06; T3: r_s = -.36, p = .04) and greater worry dysregulation (T1(trend-level): r_s = .30, p = .10; T3: r_s = .41, p = .02); at the trend-level with greater autism symptom severity at T2 and T3 (T2: r_s = .29, p = .09; T3: r_s = .33, p = .06), and with greater motivation at T1 and T2 (T1 (trend-level): r_s = .33, p = .06; T2: r_s = .38, p = .02). Greater computer enjoyment (*Hypothesis 2c: Part 1*) was significantly associated with greater motivation at T1 (r_s = .54, p <.01), at T2 (trend-level) with greater adaptive skills (r_s = .28, p = .10), and at T3 (trend-level) with emotion regulation (r_s = .32, p = .06). Neither activity showed significant associations between enjoyment and age, overall psychopathology, worry inhibition or worry coping.

Table 8. *Spearman's correlations for enjoyment: Baseline characteristics by timepoint and activity.*

	Enjoyment					
	Mindfulness			Computer		
	T1 n = 34	T2 n = 35	T3 n =35	T1 n = 35	T2 n = 35	T3 n = 35
Demographic						
Age	-.09	-.15	-.07	-.12	-.09	-.20
IQ	$-.33^{+}$	-.26	-.36*	-.18	-.35*	-.12
Clinical						
CGI-S	-.17	-.02	.20	.21	.20	-.26
SCQ	.05	$.29^{+}$	$.33^{+}$	-.17	.13	.28
ERSSQ	-.07	.14	.20	.09	.14	$.32^{+}$
BASC - Adaptive Skills	<.01	.24	.16	.27	$.28^{+}$	.26
CWMS - Inhibition	-.20	-.07	-.28	.07	.13	-.12
CWMS - Dysregulation	$.30^{+}$	.28	.41*	.15	.03	.09
CWMS - Coping	-.11	-.09	.03	-.05	.01	.10
Motivation	$.33^{+}$	.38*	.08	$.54^{**}$	.26	.04
Activity Duration (*in seconds*)	-.24	-.15	-.15	-.09	-.26	.24

^{+}p <.10; $^{*}p$ <.05; $^{**}p$ <.01
IQ = Wechsler Abbreviated Scale of Intelligence – 2 subscales; *CGI-S = Clinical Global Impression – Severity scale; SCQ* = Social Communication Questionnaire-Lifetime Version*; ERSSQ = Emotion Regulation in Social Situations Questionnaire; BASC= Behavior Assessment System for Children, 2nd Edition; CWMS = Children's Worry Management Scale*

As shown in Table 9 (*Hypothesis 2b: Part 1*), lower mindfulness SCL at T2 and T3 was associated with higher autism symptom severity (T2: r_s = -.44, p = .03; T3: r_s = -.39, p = .05), and greater ability to cope with worry (T2 (trend-level): r_s = -.36, p = .09; T3: r_s = -.49, p = .02). Lower computer SCL (*Hypothesis 2c: Part 1*) was associated with greater worry dysregulation at T2 (trend-level: r_s = .42, p = .07) and significantly associated with higher age at T3 (r_s = -.41, p = .04. No associations were observed for SCL between either activity and IQ, overall psychopathology, emotion regulation, adaptive skills, worry inhibition, or motivation.

Table 9. *Spearman's correlations for SCL: Baseline characteristics by timepoint and activity.*

	Skin Conductance Level (SCL)					
	Mindfulness			Computer		
	T1 n = 32	T2 n = 26	T3 n = 27	T1 n = 31	T2 n = 22	T3 n = 25
Demographic						
Age	-.03	.06	-.13	.13	-.19	-.41*
IQ	.02	.05	-.13	.22	.04	.24
Clinical						
CGI-S	.07	-.28	.12	<.01	-.23	-.33
SCQ	-.13	-.44*	-.39*	-.27	-.05	-.28
ERSSQ	-.08	-.14	-.16	-.21	-.09	.33
BASC - Adaptive Skills	-.02	-.07	-.22	-.20	.02	.10
CWMS - Inhibition	.03	-.26	.01	-.06	-.07	.04
CWMS - Dysregulation	.17	.20	.08	< -.01	.42^{+}	.05
CWMS - Coping	-.23	-.36^{+}	-.49*	-.15	-.08	.12
Motivation	-.03	.23	-.01	-.23	-.31	<.01
Activity Duration (*in seconds*)	-.14	.37^{+}	.30	-.02	.09	.35^{+}

^{+}p <.10; $^{*}p$ <.05; $^{**}p$ <.01
IQ = Wechsler Abbreviated Scale of Intelligence – 2 subscales; *CGI-S = Clinical Global Impression – Severity scale; SCQ* = Social Communication Questionnaire-Lifetime Version*; ERSSQ = Emotion Regulation in Social Situations Questionnaire; BASC= Behavior Assessment System for Children, 2nd Edition; CWMS = Children's Worry Management Scale*

Level 1 – Individual Differences. As per Bliese (2016), four unconditional mean models with a random effect were estimated to assess individual variation associated with each of the four outcome variables (*Hypothesis 2a, 2b, 2c: Part 2*); the intraclass correlation (ICC) was then calculated as a measure of this variation (see Appendix A for equations). The ICC associated with mindfulness enjoyment (.65) indicated that 65% of the variance in enjoyment ratings was explained by individual differences between children compared to only 21% of the variance for computer enjoyment. For SCL, 39% of the variance in mindfulness activities was explained by child-level differences, compared to 15% for computer activities.

Level 1 - Change Over Time. Next, models were fit to examine the relationship between each of the four outcome variables and time. Models were tested for both linear (*Time*) and quadratic ($Time^2$) fit. No relationship was observed between mindfulness enjoyment and time (*Hypothesis 2a: Part 2*). Computer enjoyment demonstrated significant quadratic change over time ($Time^2$: $\beta = -0.28$, $t(68) = -2.36$, $p = .02$), showing an average increase of .33 between T1 and T2, and a decrease of .23 between T2-T3 (see Fig. 1, below; *Hypothesis 2c: Part 2*). Mindfulness SCL was also not associated with change over time (*Hypothesis 2b: Part 2*); computer SCL demonstrated a linear change over time ($\beta = -.11$ $t(43) = -2.16$, $p = .04$), decreasing by an average of .11 μS at each timepoint (*Hypothesis 2c: Part 2*).

As per recommendations by Bliese (2016), model fit for all four variables was further assessed for inclusion of an autoregressive structure (to reduce multicollinearity) and a random effect for time (allowing slopes to randomly vary). Only the model for computer enjoyment and $Time^2$ was improved by the addition of lag 1 autocorrelation ($p = .04$).

(a)

(b)

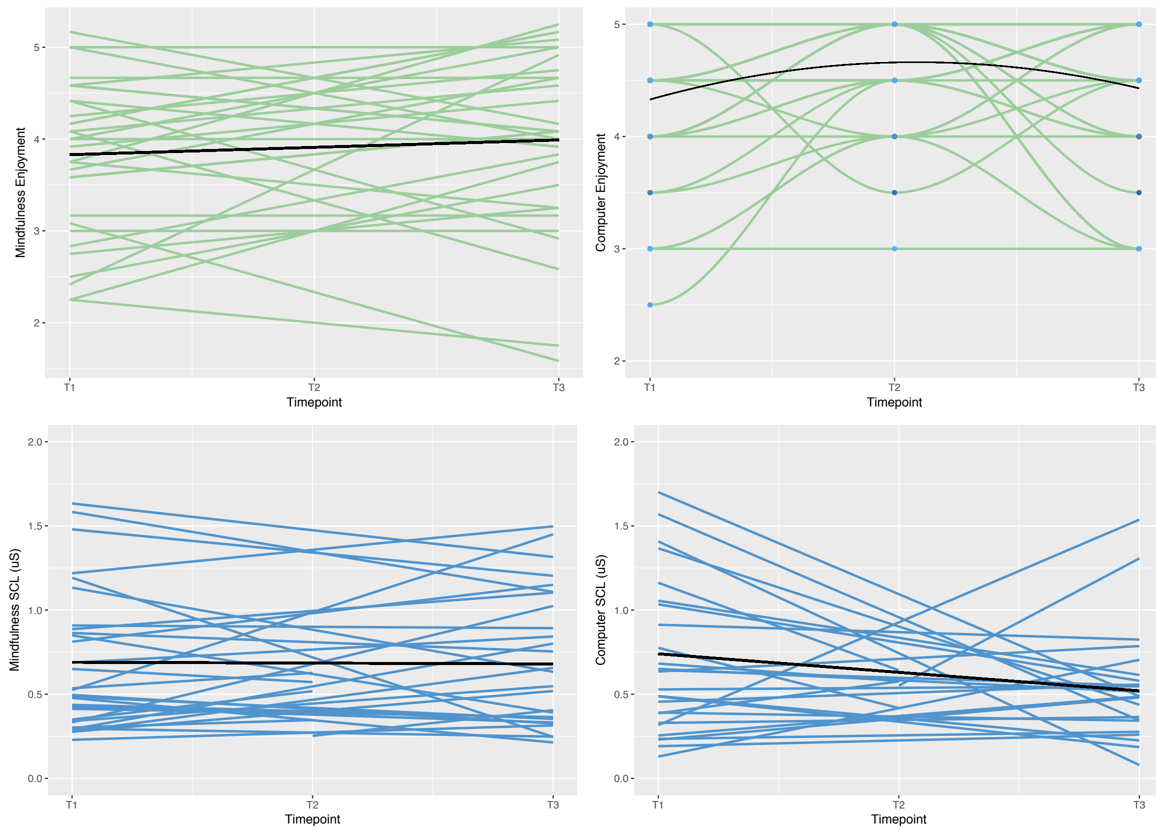

Fig. 1 *Baseline growth model comparisons for mindfulness and computer activities as a function of (a) enjoyment ratings and (b) SCL; all models are linear except computer enjoyment (quadratic).*

Level 2 – Baseline Characteristics. Finally, models were tested to assess whether significant baseline characteristics explained intercept and slope variation for enjoyment and SCL outcomes. As shown in Table 10 (*Hypothesis 2a; 2c*), greater mindfulness enjoyment at T1 was predicted by higher baseline parent-reported autism symptom scores (β = .09, SE = .08, *p* = .01), greater baseline child-reported motivation (β = .13, SE = .06, *p* = .03), and greater baseline child-reported worry dysregulation (β = .17, SE = .08, *p* = .03). IQ and emotion regulation did not significantly contribute to the mindfulness enjoyment model, and were excluded from the final specification to preserve degrees of freedom (IQ: β = -.01, *p* = .39; ERSSQ: β = .01, *p* = .26). Greater computer enjoyment at T1 was predicted by greater baseline child-reported motivation (β = .10, *SE* = .05, *p* = .04). The interaction term for motivation and Time^2 was not significant. IQ and adaptive skills did not contribute to the computer enjoyment model, and emotion regulation was excluded to preserve degrees of freedom (β < .01, p = .69).

Table 10. *Multilevel growth models: Mindfulness and computer enjoyment outcomes as a function of time and child-level predictors.*

	Child Enjoyment Ratings				
	β	(SE)	t	(df)	p
Mindfulness					
Level 1					
Individual (*Random*)	3.84	(.15)	26.12	(64)	<.001
Time	.09	(.08)	1.14	(64)	.26
Level 2					
SCQ	.09	(.03)	2.98	(29)	.01
Motivation	.13	(.06)	2.28	(29)	.03
CWMS - Dysregulation	.17	(.08)	2.28	(29)	.03
Computer					
Level 1					
Individual (*Random*)	4.33	(.10)	41.86	(66)	<.001
Time	.61	(.22)	2.78	(66)	.01
$Time^2$	-.28	(.10)	-2.70	(66)	.01
Level 2					
Motivation	.11	(.04)	2.53	(32)	.02
BASC - Adaptive	.02	(.01)	1.54	(32)	.13
Interaction					
$Time^2$ x Motivation	-.01	.02	-1.29	(66)	.20
$Time^2$ x BASC- Adaptive	<.01	<.01	.25	(66)	.80

Note. All Level 2 variables were grand-mean centered.
SCQ = Social Communication Questionnaire
CWMS = Children's Worry Management Scale
BASC= Behavior Assessment System for Children, 2nd Edition

As shown in Table 11 (*Hypothesis 2b; 2c*), lower mindfulness SCL at T1 was predicted by greater child-reported baseline worry coping skills (β = -.07, SE = .03, *p* = .05). No relationship with autism symptoms or activity duration was observed. Computer SCL at T1 was not significantly predicted by age, child-reported baseline worry dysregulation, or activity duration.

Table 11. *Multilevel growth models: Mindfulness and computer SCL outcomes as a function of time and child-level predictors.*

	Skin Conductance Level		
	β (SE)	t (df)	*p*
Mindfulness			
Level 1			
Individual (*Random*)	.69 (.08)	8.61 (38)	<.001
Time	- .02 (.06)	-0.28 (38)	.78
Activity Duration	<.01 (<.01)	2.13 (38)	.05
Level 2			
SCQ	<.01 (.02)	.12 (28)	.91
CWMS - Coping	-.07 (.03)	-2.09 (28)	.05
Computer			
Level 1			
Individual (*Random*)	.72 (.07)	10.09 (32)	<.001
Time	-.12 (.06)	-2.06 (32)	.05
Activity Duration	<.01 (<.01)	1.44 (32)	.16
Level 2			
Age	-.03 (.04)	-.75 (29)	.46
CWMS - Dysregulation	.03 (.03)	1.24 (29)	.23

Note. All Level 2 variables were grand-mean centered.
SCQ = Social Communication Questionnaire
CWMS = Children's Worry Management Scale

Discussion

This quasi-experimental study examined the experience of MBT for school-age children with autism, comparing mindfulness and computer-based therapeutic activities embedded within treatment sessions of a 10-week CBT program. To our knowledge, this is the first study to objectively measure in-vivo response to mindfulness practice for children with autism; our use of mobile wrist sensors allowed for continuous EDA collection during multiple treatment sessions, without restricting children's ability to move or respond naturally. Given that previous youth-focused studies of MBT in the field had no control group (de Bruin et al., 2015), or used a waitlist comparison (Bögels et al., 2008; Ridderinkhof et al., 2017), our inclusion of computer activities as an active comparison condition provides a novel extension of the literature. Currently, no other comparisons between MBT and internet or computer-based CBT have been undertaken for children with or without autism.

Enjoyment and Motivation. Children reported high overall enjoyment for both mindfulness and computer activities, however, mindfulness enjoyment was significantly lower relative to the ratings for computer activities at each timepoint. A small subset of children experienced mindfulness as moderately (20%) and slightly (9%) enjoyable across all timepoints (with the rest reporting high levels), whereas only 3% rated computer activities in the moderate range. This finding supports and extends previous work by de Bruin et al. (2015), who found that adolescents with autism reported moderate to high ratings of usefulness for mindfulness skills learned during treatment. Evidence from the current study further indicates that the majority of younger children with autism without intellectual disability (ages 8 – 12 years) are likely to enjoy mindfulness activities within a CBT context. However, for some, the experience may be less positive than for others. Given that multilevel modeling indicated higher initial motivation to participate in the intervention predicted higher overall enjoyment for both activities, it may be that children with low motivation (who are unaware of their difficulties or are convinced to enroll in the trial by their parent), find the computer-based activities more enjoyable than mindfulness because of the familiar game-based format. In comparison to an interactive game with animated characters, a mindfulness activity might be experienced as boring and effortful. The literature on computer and internet-based CBT for children under the age of 13 currently includes two RCTs (both evaluations of the Brave program, undertaken separately for children with and without autism): Interestingly, both groups indicated only moderate treatment acceptability at post-test (Connaughton et al., 2017; March, 2009). Treatment motivation and readiness has been linked with post-intervention improvements for adolescents with substance abuse difficulties (Becan et al., 2015), and in an app-based mindfulness study with university students, poor motivation was highlighted as an explanation for a lack of improvement (Noone & Hogan, 2018); future studies may benefit from exploring whether motivation indeed functions as a mediating or moderating factor within CBT interventions targeted to children with autism, especially for programs that include mindfulness activities.

Enjoyment, SCL and Change Over Time. Although children demonstrated the ability to differentially rate activities according to their preferences, and showed correlations among enjoyment ratings for each condition, we did not find an association between enjoyment and arousal during session-based activity practice. Two recent studies document a similar lack of relationship between child-report and EDA during active tasks: One found no association between state or trait anxiety and SCRs for children with autism participating in a stressful social task (Mertens et al., 2017), and the other found no relationship between guilt and SCL for children without autism who were tasked with imagining committing an antisocial act (Colassante et al., 2017). Interestingly, studies of arousal in response to music with non-clinical populations may help to shed light on these results: Van den Bosch, Salimpoor, & Zatorre (2013) found that for adults who listened to novel song clips, SCL was unrelated to self-reports of pleasure, but positively correlated with ratings of familiarity following repeated exposure. Some suggest that the subsequent rise in SCL may be related to dopaminergic (reward-type) processes via familiarity (Salimpoor, Benovoy, Larcher, Dagher, & Zatorre, 2011) in other words, an individual hears a familiar song clip, experiences excitement *because* of the familiarity, and arousal increases. In this study, mindfulness SCL showed a small (albeit non-significant) increase from T1 to T2; during T2, the body scan activity was repeated for a second time, and children had the opportunity to practice at home with a recording for a week. Yet our original hypothesis predicted that mindfulness arousal would decrease as a function of practice over time, given previous findings showing that MBT practice is associated with post-treatment reductions in SCL (Lush et al., 2009). The familiarity/arousal hypothesis proposes instead that there may be an initial period of excitement and/or anticipation associated with repeated exposure to a positively valenced stimulus -- that is, an increase in SCL which may occur in as little as two exposures – followed by an eventual decrease due to satiation (van den Bosch et al., 2013). An examination of the mindfulness activities in the current study support this view: Within T3, a new variation of the body scan was presented in one session, then repeated in the next; between T2 and T3, mean mindfulness SCL also showed a slight (though non-significant) decrease. Some studies within the field of music do report positive correlations between EDA and self-report of pleasure, however these results only occurred when extreme emotions were elicited, and did not involve children with autism (Grewe, Kopiez, & Altenmüller, 2009; Khalfa, Isabelle, Jean-Pierre, & Manon, 2002; Rickard, 2004; Salimpoor, Benovoy, Longo, Cooperstock, & Zatorre, 2009). As none of our activities were specifically intended to elicit strong emotions, our ability to detect changes in arousal was likely limited to a mild scope.

The linear, time-related decrease observed in computer SCL also suggests the possibility that children may have initially experienced the excitement/familiarity effect, followed by a decrease in arousal once children became more comfortable with the game. In this case, as the content of computer activities changed each session, the structure of the game could be considered as the predictable, repeated factor (i.e. on a computer, interactive, with animated characters), and may have elicited arousal satiation (and the subsequent decrease) based on children's pre-existing familiarity with these common elements.

Enjoyment, SCL and Worry. Recent longitudinal findings implicate worry/rumination as a key factor in the development of both externalizing and internalizing symptoms for boys with autism (Bos, Diamantopoulou, Stockmann, Begeer, & Rieffe, 2018). Specifically, greater baseline symptoms of youth-reported worry/rumination were found to predict greater parent-reported symptoms of disruptive behavior, depression and somatic complaints at 18-month follow-up (Bos et al., 2018). Despite a continued mix of inconclusive treatment outcomes in mindfulness-based intervention studies for youth with and without autism, findings do show consistent improvement for symptoms of rumination (Jain et al., 2007; de Bruin et al., 2015; Ridderinkhof et al., 2017). Results from the current study indicate that children who experience greater pre-treatment difficulties with core autism symptoms and worry dysregulation are likely to rate mindfulness activities as more enjoyable; such children are also likely to endorse higher levels of motivation to participate in treatment. EDA findings further indicate that children who report greater pre-treatment worry coping skills are likely to demonstrate initial SCL at levels slightly lower than the group mean. Likewise, such children may, in fact, be aware of the simple strategies they use to reduce distress (Rieffe et al., 2011); this awareness may in turn be related to increased comfort (i.e. lower arousal) when engaging in mindfulness activities for the first time.

Considering the relatively abstract nature of mindfulness activities, the direction of the relationship between autism symptom severity and mindfulness enjoyment may be considered unexpected. However, findings are in line with research from studies of children without autism that indicate response to mindfulness treatment is more likely in the case of severe clinical difficulty (Barnert et al., 2014; Lagor et al., 2013); as children in our study did not have an intellectual disability, it may be that those with greater autism symptoms were more aware of the impact in their day-to-day life, and were thus more open to trying a mode of treatment that might have seemed odd or uncomfortable at first (further supported by our finding that greater motivation to participate in therapy was also related to greater mindfulness enjoyment). The judged enjoyment of the activity may also be a result of the sensory nature of the mindfulness program, which may be a visual and tactile set of activities that has in prior research been showed to be helpful for children with autism who struggle more with the cognitive or abstract nature of tasks (Meagher, Chessor, & Fogliati, 2018; Weiss et al., 2018), fitting with those with relatively higher ASD symptom severity. The lack of relationship between ASD symptoms and ratings of the computer activities may reflect the structured manner where children are explicitly taught, within a game-like format, allowing children regardless of symptom level, to understand and enjoy, as long as they were motivated to try.

Limitations

In light of these results, a number of limitations should be considered. One major limitation to this research was the loss of cases as a result of data collection issues (e.g., sensor malfunction, poor connection due to small wrist size, corrupted files, missing files, activities not administered, activities administered out of order). Additionally, EDA and video were not originally time-locked, requiring all activity segments to be timed and trimmed by hand. Consequently, if it was impossible to match the EDA output with the start of data collection on camera within a 1-5-second error margin, the entire session was discarded in order to ensure that all sections of timed, trimmed activity data were reliable. While multilevel modeling allowed for the complete use of all existing data across combined timepoints, and the repeated, nested format increased power, there is still a question as to whether results would generalize to the entire CBT sample. Future work that compares full-length mindfulness and computer-based CBT interventions is necessary to untangle questions of efficacy and adherence, which we were not able to address in this study.

Due to the manualized therapy format, we were unable to counterbalance activities to control for order effects. One explanation for children's high ratings for both computer and mindful activities, may be that after completing the computer game -- a positive experience – subsequent experiences were more likely to be positive; theory also suggests that children are prone to rate their experience based on their immediate emotions, even when questions are retrospective (Read & MacFarlane, 2006; Read & Macfarlane, 2002). Since ratings for both activities were completed at the end of the session, reporting may also have been affected by children's feelings regarding the overall experience. Future work is needed to untangle whether children's mindfulness enjoyment is contingent on experiencing enjoyment of a preceding activity. In addition, the mindfulness condition received more practice than the computer condition: While activities in the computer condition changed each week and were not practiced at home, mindfulness activities such as the Body Scan were repeated in multiple sessions, and children were provided with a recording of the mindfulness activity by their therapist and encouraged to practice as part of their weekly homework. We realize that this imbalance across conditions reduces the internal validity; this was also unavoidable given the structure of the intervention.

Two factors which were not included in our analysis - skin temperature and motor movement – have been highlighted as possible moderators of EDA response in best practice recommendations (Boucsein et al., 2012). In consideration of our small sample size, we elected not to include the additional two variables in our analysis, however both were assessed qualitatively: Each participant's temperature graph was inspected visually for deviations in the shape of the curve (indicating an unusual drop in temperature). Video of the activities was then assessed for signs of any movement that might have impacted the Q-sensor, and checked against the EDA graph to look for spikes (a sudden drop in connection followed by an immediate high peak); these segments typically included multiple instances of connection drops and erroneous spikes and were therefore discarded.

Finally, although studies of user-centered design for children's computer programs report that children within this age group respond to visual analogue scales with appropriate variability (Read & MacFarlane, 2006), overall, the face-based Likert scale used to measure children's enjoyment may have lacked the specificity and sensitivity to detect associations with children's physiological arousal, as well as changes in children's preferences over time. Studies highlight the difficulty of accurately capturing the construct of "fun" in child-report (Read & MacFarlane, 2006; Read & Macfarlane, 2002), suggesting that it may be more meaningful to ask children how much they would want to repeat an activity (Read & Macfarlane, 2006).

Conclusion

There is a critical need to understand how to help youth with autism engage with therapy processes in a manner that encourages generalization, practice and long-term maintenance of new skills. Involving children in the process of understanding therapeutic experiences requires great time, but also provides invaluable potential for insight. The different patterns of association demonstrated between the two activity conditions in this study highlight the importance of employing an active comparison in intervention research. Multilevel modeling indicated that motivation may be an important predictor of children's enjoyment for both mindfulness and computer activities, underscoring the need to consider this characteristic when children enter into therapeutic treatment. In addition, potentially unique to mindfulness specifically, greater child clinical characteristics of autism symptomatology and greater worry dysregulation, predicted greater mindfulness enjoyment. These findings lay important groundwork towards establishing a psychological profile of school-age children with autism who may derive particular gain from mindfulness and computer-based therapeutic activities. Finally, the exploration of EDA in the current real-world context of therapy shows promise, but ultimately raises more questions than it does answers, highlighting the need for greater methodological control and rigorous design. Clearer understanding of the use of tools such as the Q-Sensor is therefore necessary, before clinical utility can be achieved in these contexts.

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Appendix A - Notation For Multilevel Growth Modeling

As illustrated below (per notation by Bryk & Raudenbush (1992) and instructions by Bliese (2016), and Shek & Ma (2011)), in the unconditional model, the random effect specifies a common intercept (γ_{00}), an overall mean that varies for each individual. The dependent variable (Y_{ij}) is therefore a function of this mean intercept, along with between-group error (u_{0j}) and within-group error (r_{ij}):

$$Y_{ij} = \gamma_{00} + u_{0j} + r_{ij}$$

The intraclass correlation (ICC) is calculated via $\tau_{00}/(\tau_{00} + \sigma^2)$, where τ_{00} represents the between-group intercept variance associated with u_{0j}, and σ^2 represents the within-group residual variance associated with r_{ij} (Bryk & Raudenbush, 1992).

There are two levels within growth models: Repeated measurements are specified as Level-1 variables and ordered by time, and baseline characteristics are entered in Level 2 (Bliese, 2016; Shek & Ma, 2011):

Level 1:

$Y_{ij} = \beta_{0j} + \beta_{1j}\,(\text{Time}) + r_{ij}$

$\beta_{0j} = \gamma_{00} + u_{0j}$ = overall mean (*outcome variable*) + error

β_{1j} = linear slope for individual *i* at Time *t*

r_{ij} = residual variance at Time *t*

Level 2:

$Y_{ij} = \pi_{0j} + \pi_{1j}(Time_{ij}) + r_{ij}$

Y_{ij} = grand mean for outcome variable at Time *t*

$\pi_{0j}{}^{*} = \gamma_{00}$ (overall intercept/outcome variable*) + β_{1j} (baseline characteristic) + u_{0j} (error) **

$\pi_{1j} = \beta_{10}$ (overall slope/outcome variable) + β_{2j} (baseline characteristic) + u_{1j} (error) ***

* = Grand mean at T1 (*initial status*)

** = Difference between overall intercept, and overall intercept after accounting for contribution of characteristic variable

*** = Difference between overall slope, and overall slope after accounting for contribution of characteristic variable

Appendix B - Descriptives by Weekly Session

Table 12. *Descriptives for enjoyment by activity and weekly sesssion.*

	Enjoyment																	
	S1			S2			S3			S5			S6			S7		
	M	*(SD)*	*Md*	*M*	*(SD)*	*Md*	*M*	*(SD)*	*Md*	*M*	*(SD)*	*Md*	*M*	*(SD)*	*Md*	*M*	*(SD)*	*Md*
Mindfulness	n = 34			n =35			n =32			n =35			n = 32			n =32		
	3.9	(1.1)	4	3.8	(1.2)	4	3.8	(1.4)	4	3.9	(1.1)	4	4.1	(1)	4	4	(1.2)	4
Computer	n = 35			n = 34			n = 33			n = 35			n = 32			n = 35		
	4.3	(.8)	4	4.4	(.9)	5	4.5	(.8)	5	4.9	(.5)	5	4.8	(.6)	5	4.1	(1.2)	5

Note: As no mindfulness activities were administered in Sessions 4, 8, 9 and 10, these sessions have been omitted.

Table 13. *Descriptives for SCL by activity and weekly session.*

	Enjoyment																	
	S1			S2			S3			S5			S6			S7		
	M	*(SD)*	*Md*	*M*	*(SD)*	*Md*	*M*	*(SD)*	*Md*	*M*	*(SD)*	*Md*	*M*	*(SD)*	*Md*	*M*	*(SD)*	*Md*
Mindfulness	n = 21			n =19			n =14			n =20			n = 21			n =19		
	.58	(.34)	.47	.65	(.42)	.55	.63	(.45)	.51	.93	(.66)	.72	.78	(.51)	.65	.53	(.25)	.53
Computer	n = 21			n = 14			n = 15			n = 16			n = 17			n = 20		
	.83	(.54)	.78	.55	(.37)	.47	.76	(.51)	.60	.53	(.28)	.49	.72	(.46)	.59	.43	(.19)	.36

Note: As no mindfulness activities were administered in Sessions 4, 8, 9 and 10, these sessions have been omitted.